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Population density and biomass of earthworms in agro-ecosystems of the Mariut coastal desert region in Egypt[1])

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With 7 figures

Key words: Earthworms, reclaimed land, deserts, Mariut

1. Introduction

Earthworms are generally known to be absent from deserts (Edwards & Lofty 1972). In the Sahara desert, however, earthworms were found in some of the isolated oases (cf. Khalaf & Ghabbour 1968a; Niethammer 1971; Ghabbour 1976). *Allolobophora caliginosa* (Savigny 1826) exists in most of these oases together with other species of much more limited distribution. *Eisenia rosea* (Savigny 1826) exists also in the oases nearer to the Mediterranean coast and seems to be a relict of old migrations, as discussed by Khalaf & Ghabbour (1968a, b). Programmes of land reclamation started in 1955 in the Mediterranean coastal desert west of Alexandria (UNDP/FAO 1971). Already in 1959, the presence of *A. caliginosa* as a colonizer in newly reclaimed areas on this coast was noted (Khalaf & Ghabbour 1963).

Earthworms have a special importance in such newly reclaimed soils. Yet, they are not utilized to their full potential for various reasons discussed by Bouché (1972). Nevertheless, they were artificially introduced into newly reclaimed desert lands in Uzbekistan (Ghilarov & Mamayev 1963) with apparently considerable success (Ghilarov & Mamayev 1966). A similar experiment would be highly beneficial to soils of the Mariut region to reduce cost of fertilizers. The present study was carried out to identify the factors which influence the establishment of earthworm populations in these agro-ecosystems (both rain-fed and irrigated), in order to provide recommendations on the introduction and maintenance of earthworm populations in agro-ecosystems of the Mariut region.

2. Material and methods

The Mariut region is characterized by a series of ridges and depressions parallel to the coast. Rainfall is about 180 mm/year but may vary from 50 to 300. A detailed description of the area is given by Ayyad & Ghabbour (1977). Rain-fed cultivation of barley, figs, olives and almonds is practiced in some favoured depressions, or in the fertile karm soils (artificial ridges of the Graeco-Roman period, Kassas 1972). Irrigated farms, on the other hand, lie south of the Salt Marsh in areas that have been levelled and ploughed and then planted for a few years with alfalfa, to improve soil properties, before being planted with the final crops. These may be field crops (maize and clover, *Trifolium alexandrinum* L.) or fruit trees (vines, pears).

Nine farms were investigated in the present study: 6 rain-fed and 3 irrigated. Earthworms were found in 3 only of the rain-fed farms and in all irrigated farms under study. The rain-fed farms in which earthworms appeared were: (1) fig at Gharbaniat, (2) almond at Gharbaniat, and (3) olive at Burg El-Arab. The irrigated farms were: (4) "new" vine at Gharbaniat (established about 1974),

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[1]) Paper presented to the Vth International Colloquium on Terrestrial Oligochaeta (Moscow, (6—11 Oct., 1980; read *in absentia*).

This paper is dedicated to the memory of the late Prof. Dr. Khalaf El-Duweini (1914—1979), who pioneered and established the tradition of studies on Oligochaeta in Egypt.

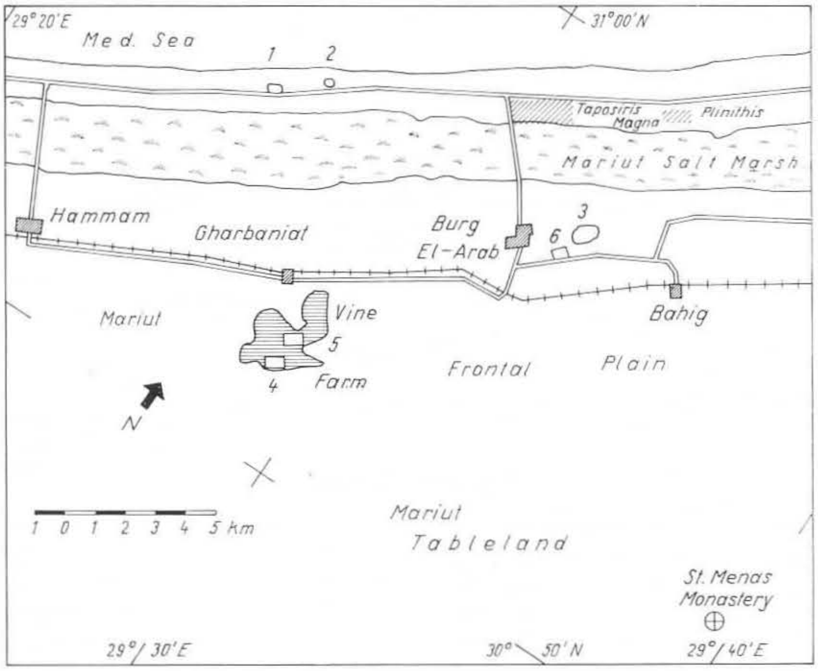


Fig. 1. Locality map of the study area.

Table 1. Some characteristics of the six agro-ecosystems in the Mariut coastal desert region in Egypt and in which earthworms were found

Farm	Fig (1)	Almond (2)	Olive (3)	"new" Vine (4)	"old" Vine (5)	Field Crop (6)
Total gravel & sand (a) as %	*78.9*	*78.9*	*32.0*	*54.7*	*54.7*	*49.6*
Saturation percentage (b)	*37.1*	*37.1*	*46.2*	*34.7*	*34.7*	*36.9*
Distances between trees in m	5.6×7.3	5.5×7.5	4.5×5.0	2.5×1.8	2.5×1.8	—(c)

a) From data given by GOMAA *et al.* (1978) and calculated by method given by KHALAF & GHABBOUR (1965b).

(b) From data given by GOMAA *et al.* (1978) and averaged. Data used in (a) and (b) relate to the upper 60 cm layer of soil, in which earthworms are normally active.

(c) The field crops farm was originally a rain-fed olive farm to which irrigation water was brought to cultivate annual crops, with the consequent deterioration of olive trees which were eventually uprooted in July 1979.

(5) "old" vine at Gharbaniat (established about 1971) and (6) a field crop rotation (maize and clover) at Burg El-Arab (Fig. 1). A detailed description of these farms is given elsewhere (GHABBOUR & SHAKIR, in preparation). However, some of the essential features are given in Table 1. GOMAA *et al.* (1978) gave a detailed description of the soils of these farms.

The sampling programme was continued from spring 1977 till autumn 1978 so that each farm was sampled in five seasons during this period. Samples were taken from every farm in 10 quadrats (50 × 50 cm, 60 cm deep) selected along a random line within the center of the farm, between trees and shrubs, to avoid damaging the roots. The soil fauna was extracted from the soil core brought out of these quadrats by digging, either by sieving (farms 1 and 2) or by hand-picking (all other farms). After sieving or hand-picking, the animals and litter were brought back to the laboratory and animals were sorted out under a binocular microscope (×100) and preserved in 70% ethanol or 4—6% formalin. The weights given here refer therefore to formalin-preserved specimens which, for practical purposes, are considered equivalent to fresh weights. Soil samples were taken from the quadrats and analysed as to water and organic matter content in the usual ways.

Soil hydrature (% SH) is calculated from the saturation per cent data given by GOMAA *et al.* (1978) as: $\frac{\text{rel. soil moisture}}{\text{rel. saturation}} \times 100.$

Data of population density (PD), biomass (BM) and absolute frequency (AF), were synthesized into the importance value index (I.V.), which is log (PD × BM × AF), as used by GHABBOUR & SHAKIR (1980). Mathematical treatment of the data (simple and multiple regressions) were performed by an HP 25 C and TI 58.

3. Results

Table 2 shows results of analyses for average soil water content at 5, 30 and 60 cm deep (as %) and organic matter content at 5 cm deep (as %) in all seasons of sampling in agro-ecosystems in which earthworms appeared at one time or another. Earthworms of the species *Allolobophora caliginosa* were found in the rain-fed fig farm at Gharbaniat with an annual AF of 7.6%, when soil moisture reached a maximum of 10.1% at 60 cm. Table 3 shows that PD was an average 11.3/m^2 at this season (winter) and declined to 0.4/m^2 in spring when soil moisture averaged 4.8% for the whole profile. *Allolobophora caliginosa* appeared also in the nearby almond farm in the same season (winter 1978) probably as an outlying population with a low density of 0.4/m^2 at an average soil moisture of 5.3%. The marginal nature of this population is evident from its disappearance in summer 1978 while the main fig population still persisted at a tailing off PD of 0.4/m^2.

A. caliginosa appeared also in the rain-fed olive farm but in one season only, autumn 1978, when soil moisture reached an exceptionally high level of 20.8% on the average, with a PD of 3.2/m^2. In the two irrigated vine farms, *A. caliginosa* was also the earthworm species that made its appearance, but still not as a permanent population. It appeared only in the summer season (1977 & 1978) in the "new" vine farm. Its disappearance in other seasons is certainly not due to cold or to low moisture levels, although low moisture level in summer 1978 depressed its PD from 9.2/m^2 in summer 1977 (at an average 15.9% soil moisture) to 0.8/m^2 at an average 7.4% soil moisture. In the "old" vine, on the other hand, the disappearance of *A. caliginosa* in summer 1978 is clearly due to low soil moisture in that season. The highest PD recorded of 104.5/m^2 was in this farm at 20.2% soil moisture (on the average).

Eisenia rosea was found in the field crops farm in all 5 seasons of sampling with mean PD ranging from 2.0 to 43.6/m^2. This farm appears to enjoy uninterrupted high and adequate levels of soil moisture (12.7—15.2%) as well as organic matter (1.1—1.4%). Fig. 2 shows the relationship between PD and BM in all 17 cases in which earthworms appeared. The data for *E. rosea* are easily seen to be within the range for *A. caliginosa*. It is to be noted that earthworms were mostly juvenile with an average weight of 48.2 mg (± 13.9) for *A. caliginosa* and 53.3 mg (± 23.8) for *E. rosea*, which are not significantly different from each other.

Table 2. Seasons of sampling, average soil moisture in the upper 60 cm layer (as %), and organic matter content in the upper 5 cm layer (as %), in the six agro-ecosystems in which earthworms were found

1. Fig farm at Gharbaniat

	spr. 77	aut.	win. 78	spr.	sum.
Soil moisture ($\bar{x}$)	6.32	3.39	7.69	4.84	3.26
Org. matter	0.39	0.93	0.85 *	0.29 *	0.34 *

2. Almond farm at Gharbaniat

	spr. 77	aut.	win. 78	spr.	sum.
Soil moisture ($\bar{x}$)	3.15	2.50	5.33	2.83	2.48
Org. matter	0.37	0.29	0.37 *	0.19 *	0.54

3. Olive farm at Burg El-Arab

	sum. 77	aut.	win. 78	spr.	aut.
Soil moisture ($\bar{x}$)	8.01	8.40	14.87	8.71	20.81
Org. matter	1.17	0.99	1.66	1.50	1.19 *

4. "New" vine farm at Gharbaniat

	sum. 77	win. 78	spr.	sum.	aut.
Soil moisture ($\bar{x}$)	15.90	9.67	9.01	7.38	8.37
Org. matter	0.65 *	0.73	0.94	0.91 *	0.78

5. "Old" vine farm at Gharbaniat

	sum. 77	win. 78	spr.	sum.	aut.
Soil moisture ($\bar{x}$)	18.97	13.28	20.16	7.36	12.80
Org. matter	0.81 *	0.87 *	1.20 *	0.93	1.11 *

6. Field crops farm at Burg El-Arab

	aut. 77	win. 78	spr.	sum.	aut.
Soil moisture ($\bar{x}$)	12.66	16.58	16.52	15.16	18.35
Org. matter	1.10 *	1.42 *	1.40 *	1.06 *	1.12 *

Note: * = seasons in which earthworms appeared.

Table 3. Population density/m² (PD), biomass in mg/m² (BM) with standard error (±), absolute frequency % (AF), and importance values (IV) of earthworms in six agro-ecosystems in the Mariut costal desert region in Egypt

1. Fig farm at Gharbaniat *(A. caliginosa)*

Season	win. 78	spr. 78	sum. 78	ant.*)	Annual mean
PD	11.3	0.4	0.4	—	2.4
±	7.7	0.4	0.4	—	—
BM	855.3	12.8	20.4	—	177.7
±	602.0	12.8	20.4	—	—
AF	16.7	10.0	11.1	—	7.6
IV	5.2	1.7	2.0	—	3.5

Table 3. (cont'd)

2. Almond farm at Gharbaniat *(A. caliginosa)*

Season	win. 78	spr. 78	sum.*)	ant.*)	Annual mean
PD	0.4	0.8	—	—	0.2
±	0.4	0.5	—	—	—
BM	23.2	44.0	—	—	13.4
±	23.2	42.3	—	—	—
AF	10.0	20.0	—	—	6.0
IV	2.0	2.8	—	—	1.3

3. Olive farm at Burg El-Arab *(A. caliginosa)*

Season	win.*)	spr.*)	sum.*)	aut. 78	Annual mean
PD	—	—	—	3.2	0.6
±	—	—	—	1.7	—
BM	—	—	—	295.6	59.1
±	—	—	—	159.8	—
AF	—	—	—	40.0	8.0
IV	—	—	—	4.6	2.5

4. "New" vine farm at Gharbaniat *(A. caliginosa)*

Season	sum. 77	sum. 78	Annual mean
PD	9.2	0.8	2.0
±	6.5	0.8	—
BM	278.0	94.0	74.4
±	252.1	94.0	—
AF	20.0	10.0	6.0
IV	4.7	2.9	3.0

5. "Old" vine farm at Gharbaniat *(A. caliginosa)*

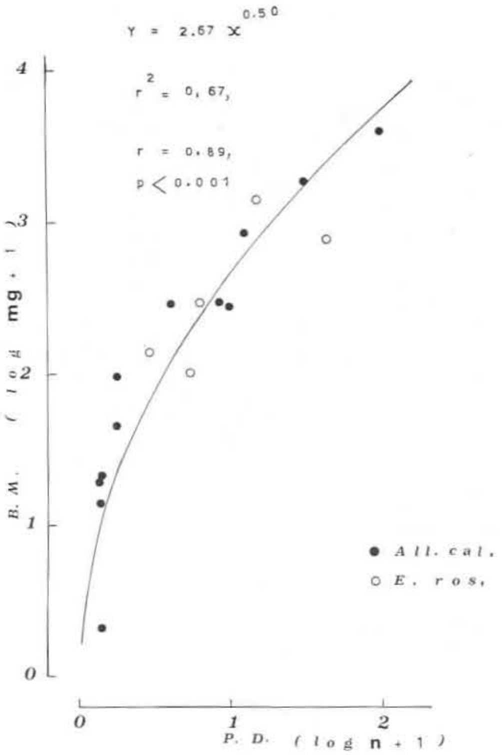
Season	sum. 77	win. 78	spr. 78	aut. 78	Annual mean
PD	0.4	7.6	104.5	30.7	28.6
±	0.4	3.3	20.8	9.7	—
BM	1.2	283.2	3,866.0	1,806.0	1,191.3
±	1.2	126.1	897.8	775.7	—
AF	10.0	50.0	100.0	100.0	52.0
IV	0.7	5.0	7.6	6.7	6.2

6. Field crops farm at Burg El-Arab *(E. rosea)*

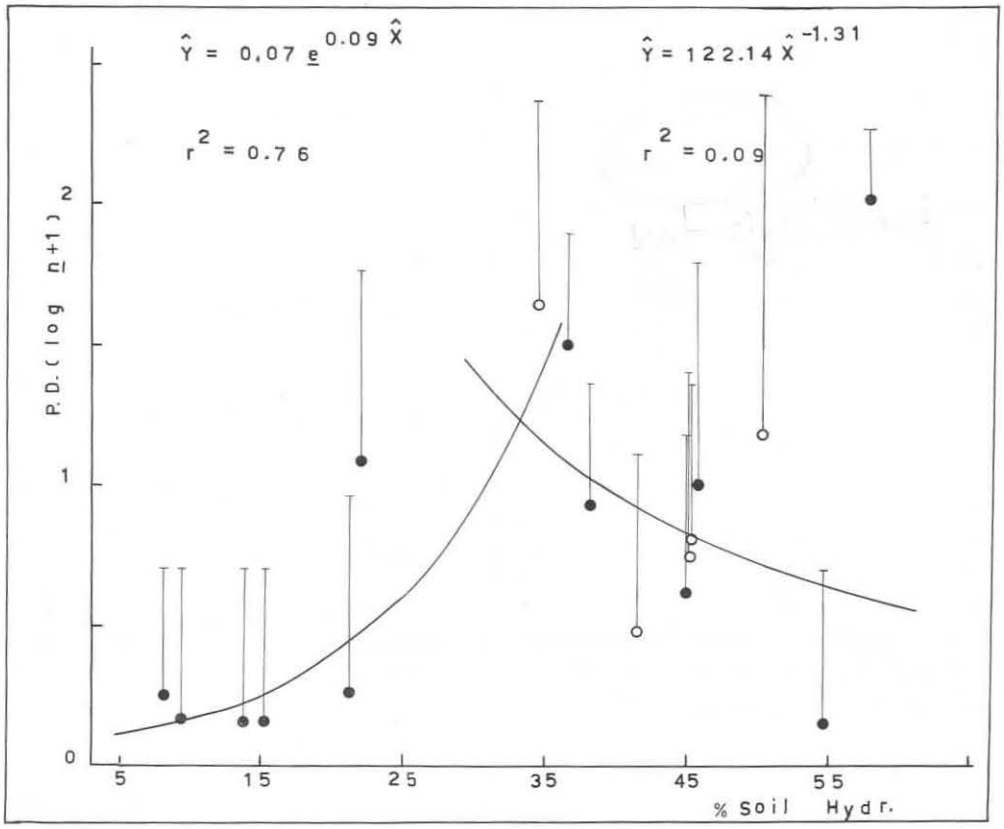
Season	aut. 77	win. 78	spr. 78	sum. 78	aut. 78	Annual mean
PD	43.6	5.5	4.5	2.0	14.0	13.9
±	23.6	3.5	3.0	1.4	0.9	—
BM	752.8	291.5	101.0	144.8	1,421.6	542.3
±	437.1	170.6	64.2	100.9	44.5	—
AF	60.0	37.5	37.5	20.0	70.0	45.0
IV	6.3	4.8	4.2	3.8	6.1	5.5

Note: Each figure for a season is the mean of a sample of 10 quadrats 50 × 50 × 60 cm each.

* At this time not sampled.



Y = 2.67 X^0.50
r² = 0.67,
r = 0.89,
p < 0.001
B. M. (log mg + 1)
0
1
2
3
4
0
1
2
P. D. (log n + 1)
● All. cal.
○ E. ros.



Ŷ = 0.07 e^0.09 X̂
r² = 0.76
Ŷ = 122.14 X̂^-1.31
r² = 0.09
P.D. (log n+1)
0
1
2
5
15
25
35
45
55
% Soil Hydr.

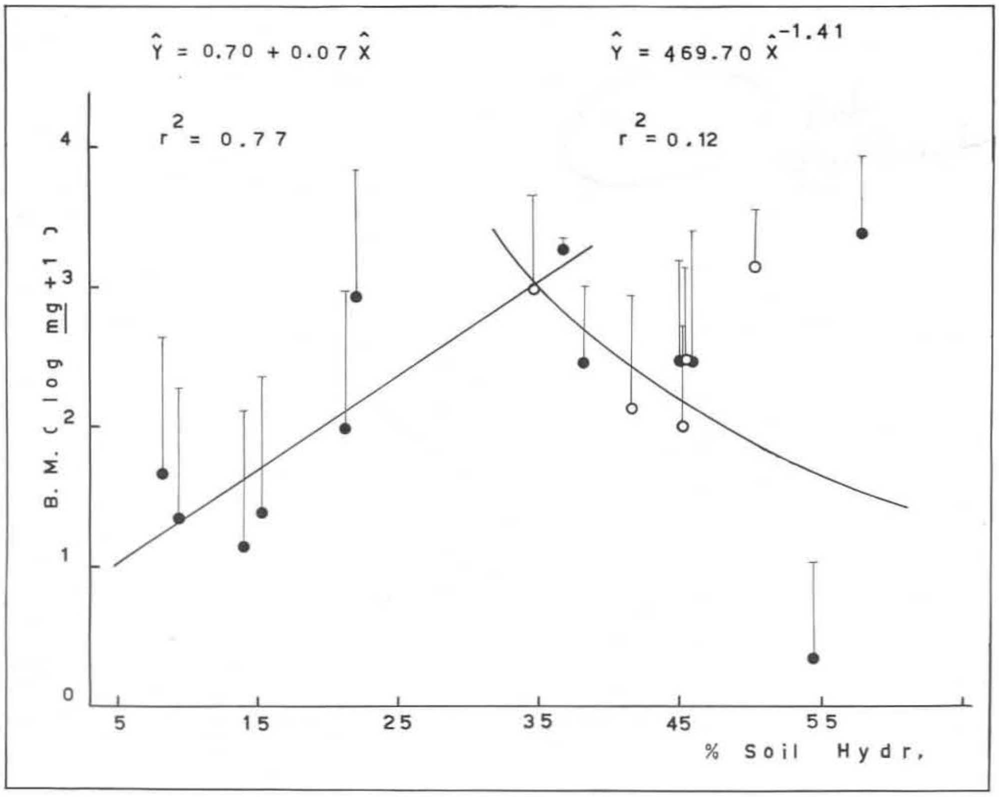


Fig. 4. Relationship between soil hydrature % and biomass of earthworms (as log mg + 1). The vertical lines show the maximum biomass recorded in each sampling.
$Y = 0.5560 + 0.1001x - 0.0012x^2$, $r^2 = 0.2494$.

4. Discussion

It is necessary to discover the extent by which each of the important factors affecting populations of earthworms in these rain-fed and irrigated agro-ecosystems, determines these variables. Temperature is clearly not one of the decisive factors in this region of mild winters (Ayyad & Ghabbour 1977), since earthworms appeared in these agro-ecosystems whenever soil moisture was adequate regardless of the season. The little influence that temperature has on the distribution of earthworms in Egypt as a whole was already pointed out by Khalaf & Ghabbour (1965a). The two most important factors are probably moisture availability (not moisture content as such) and organic matter content. Figs. 3 and 4 show the relationship between PD and BM on one hand, with per cent soil hydrature (% SH). Saturation per cent is higher than water-holding capacity, so that when soil moisture is calculated as % WHC, the resulting value is higher than when it is calculated as % SH. The relationships in Fig. 3 and 4 appear to be positive till a soil hydrature of 35%, and negative afterwards, being sharper in the case of BM. High levels of SH may

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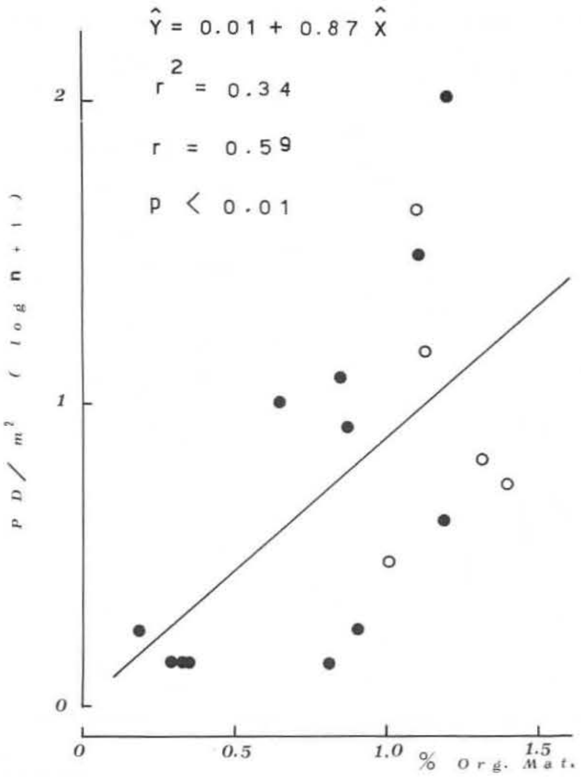
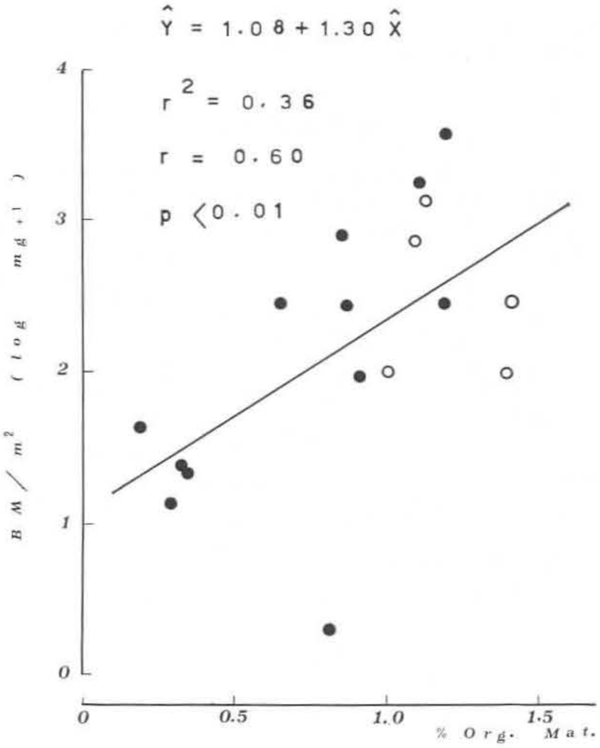
Fig. 2. Relationship between mean population density of earthworms (as log n + 1) and biomass (as log mg + 1).

Fig. 3. Relationship between soil hydrature % and population density of earthworms (as log n + 1). The vertical lines show the maximum population density recorded in each sampling.
$Y = 0.0459x - 0.0004x^2 - 0.2075$, $r^2 = 0.3152$.


Ŷ = 0.01 + 0.87 X̂
r² = 0.34
r = 0.59
p < 0.01
PD / m² (log n + 1)
0
1
2
0
0.5
1.0
1.5
% Org. Mat.


Ŷ = 1.08 + 1.30 X̂
r² = 0.36
r = 0.60
p < 0.01
BM / m² (log mg + 1)
0
1
2
3
4
0
0.5
1.0
1.5
% Org. Mat.

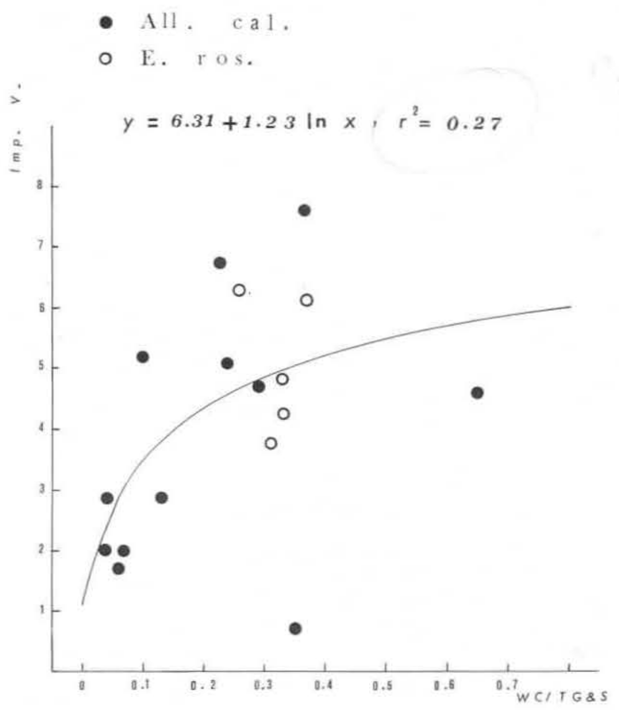


Fig. 7. Relationship between importance value of earthworms (an index of density, biomass and frequency) and water content/total-gravel-and-snad ratio in soil (an index of water availability).

be associated with extremely low PD's like those of very low SH's. Khalaf & Ghabbour (1968c) showed that the optimum soil moisture for *A. caliginosa* in sandy soils of the Burg-El-Arab region, with 28.6% WHC, was in the range of 17—27% (60—95 WHC). The 35% SH optimum shown in the present study may therefore be equivalent to the 60—95% of the water-holding capacity optimal range of sandy soils, especially nearer to the lower value which is more optimal than the higher value. According to Khalaf & Ghabbour (1968c), survival of *A. caliginosa* was much longer at 17% soil moisture than at either 22 or 27% soil moisture, in these sandy soils.

Figs. 5 and 6 show the relationship between PD and BM, on one hand, with soil organic matter content. It is clear that if soil hydrature is favourable, the relationship with organic matter, in these desert soils, is simply linear and positive; again sharper in the case of biomass. One would naturally expect from these findings that if favourable conditions occur in the soil, young worms hatch from their cocoons or invaders move from nearby banks of irrigation canals or manure heaps, so that PD is first increased. Some time later, when these worms have fed adequately, BM is increased. This is perhaps why PD is more variable than BM. The importance value (IV), being a synthesis of PD, BM and frequency data, can be profitably used to determine the effect of environmental factors on the combined population characteristics. Fig. 7 shows the relation of IV with another index of water availability, namely, the ratio of soil water content to total gravel and sand (WC/TG & S). This index was successfully used by Khalaf & Ghabbour (1965b) to interpret density and

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Fig. 5. Relationship between population density of earthworms (as log n + 1) and organic matter content (as %) in the upper 5 cm layer of soil.

Fig. 6. Relationship between biomass of earthworms and soil organic matter content.